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INVESTIGATION OF REMOTE SENSING TECHNIQUES AS INPUTS TO OPERATIONAL RESOURCE MANAGEMENT MODELS

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16. Abstract Preliminary evaluation of a NASA-developed CCT rectification program is reported. Land use studies center on determining classification accuracies of agricultural land, as interpreted from a variety of data sources, over a 93,000 hectare test area within the Belle Fourche River Basin. LANDSAT surface water inventory capabilities are also being evaluated using the same test area. LANDSAT CCT data have been successfully used for initial Black Hills aspen mapping efforts.

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PREFACE

During this reporting period, a NASA-developed LANDSAT CCT rectification program has been obtained. Preliminary evaluation of the program package has begun. Basin-wide Level I Land Use data have been visually interpreted from LANDSAT imagery. Analysis of classification accuracies has begun on a variety of data sources for a ten-township (93,312 hectare) test area. This same area is the location for a surface water inventory analysis which indicates that under certain situations, visual interpretation of LANDSAT MSS 7 data provides more current surface water data than are available on existing 1:24,000 USGS Quadrangle maps. Preliminary aspen-mapping results reveal that digital analysis of LANDSAT CCT data may be a potential source for aspen stand mapping/monitoring procedures.

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INTRODUCTION

This is the fourth quarterly report of LANDSAT Follow-On Project, NASA Contract NAS5-20982. LANDSAT and aircraft remotely-sensed data are being evaluated by three South Dakota governmental agencies: the Game, Fish and Parks Department (GF&P), the State Planning Bureau (SPB), and the Department of Natural Resources Development (DNRD). Remote sensing data and associated interpretive techniques are being studied to determine input applicability to present operational state programs. Emphasis is placed on procedures which can be easily initiated using present state government financial and personnel restraints. The study site is the 824,000 hectare (2,035,000 acre) Belle Fourche River Basin in western South Dakota. Interpretations reported herein center around land use evaluations, surface water mapping and aspen delineation using LANDSAT imagery. An MSS CCT rectification program is also being evaluated.

PROBLEMS

Registration of LANDSAT data products has been inconsistent. Single-scene data registration, as observed on LANDSAT imagery obtained via an EROS Data Center standing order, has for some scenes been acceptable and for others unacceptable. For some scenes, color composite registration is better on RSI-produced color composites as compared to the EROS color composite. For other scenes, the EROS color composite appears better. A series of MSS scenes have been ordered with a request to attempt registration. Such scenes will provide additional information pertaining to the registration problem.

ACCOMPLISHMENTS

Digital Image Rectification System

The Remote Sensing Institute obtained a NASA-developed programming package called Digital Image Rectification System (DIRS). DIRS was designed to operate on digital LANDSAT MSS imagery and to cartographically correct the data to a Universal Transverse Mercator (UTM) grid system (1).

Selection of approximately twenty Ground Control Points (GCP) per scene is recommended. The GCP's are geographic or physiographic landmarks (e.g. airport runway intersection) which can be easily found on the LANDSAT image and on reference maps (1:24,000 USGS Quadrangle). After the GCP's are selected and the approximate pixel coordinate for each GCP is established, DIRS produces a shade print, Figure 1, of the GCP. The print is used for verification of the GCP location. MSS pixels are sequentially numbered on all sides of the shade print and the GCP coordinate is now more precisely located via this pixel information. The pixel coordinates are used as input for the next DIRS step which provides for expansion of the MSS data at the GCP site. A series of 3x3, 5x5 and 10x10 cubic convolution expansion line-printer maps, Figures 2, 3, and 4, are generated. These maps are being used in conjunction with the 1:24,000 USGS Quadrangle maps in accurately correlating the USGS and DIRS GCP locations. Using the 10x10 expansion and the Quadrangle map, a UTM coordinate is assigned to the GCP pixel coordinate in terms of tenths of a MSS pixel. For example, the GCP pixel coordinate for Figure 4 is 2364.2(X), 1803.4(Y) and the corresponding UTM coordinate is 650,426E, 4,891,064N. Similar procedures are followed for all designated GCP's. With this input, DIRS generates data which allow for

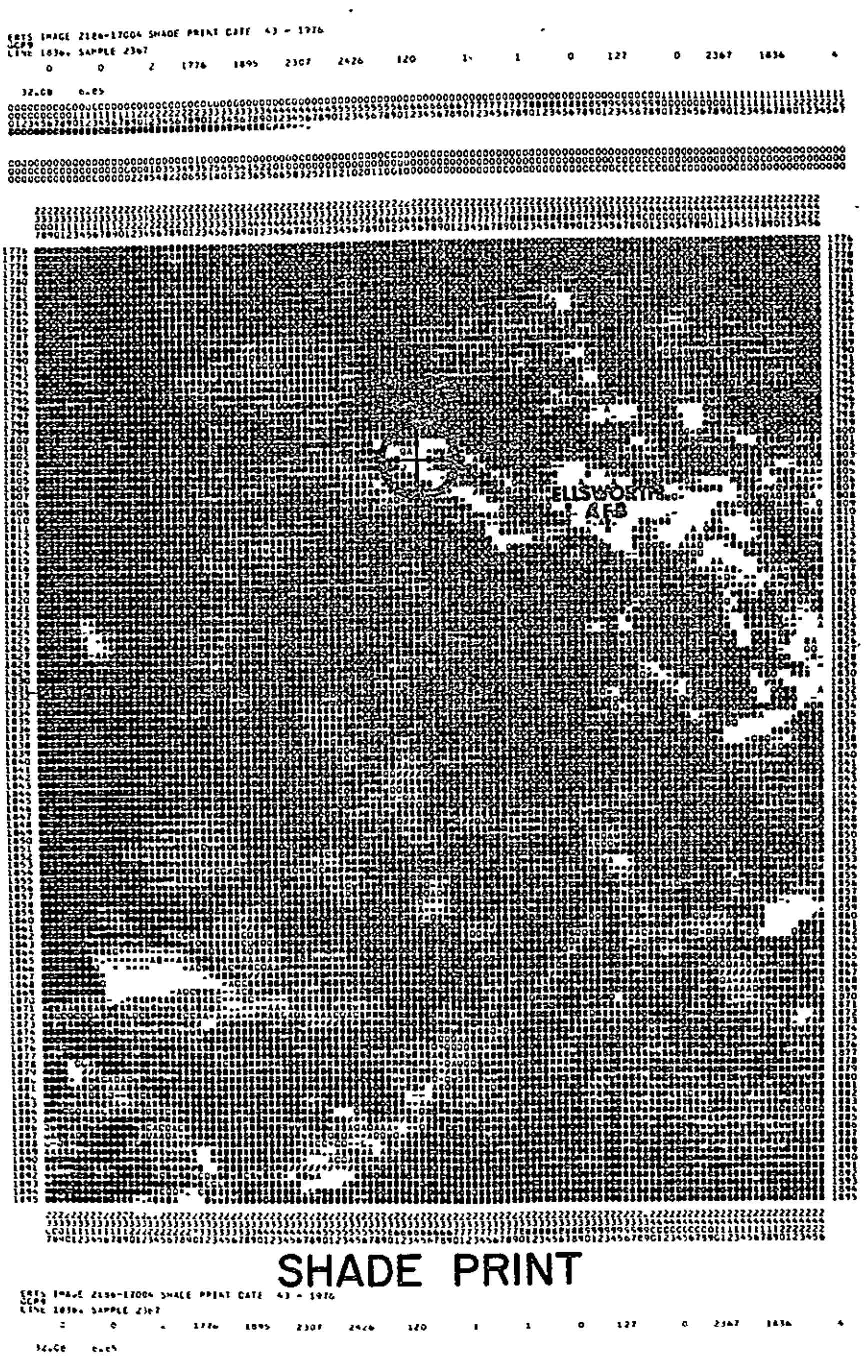

Figure 1. DIRS - generated shade print of a runway intersection ground control point (GCP).

Figure 2. DIRS - generated 3x3 cubic convolution expansion of runway intersection of Figure 1.

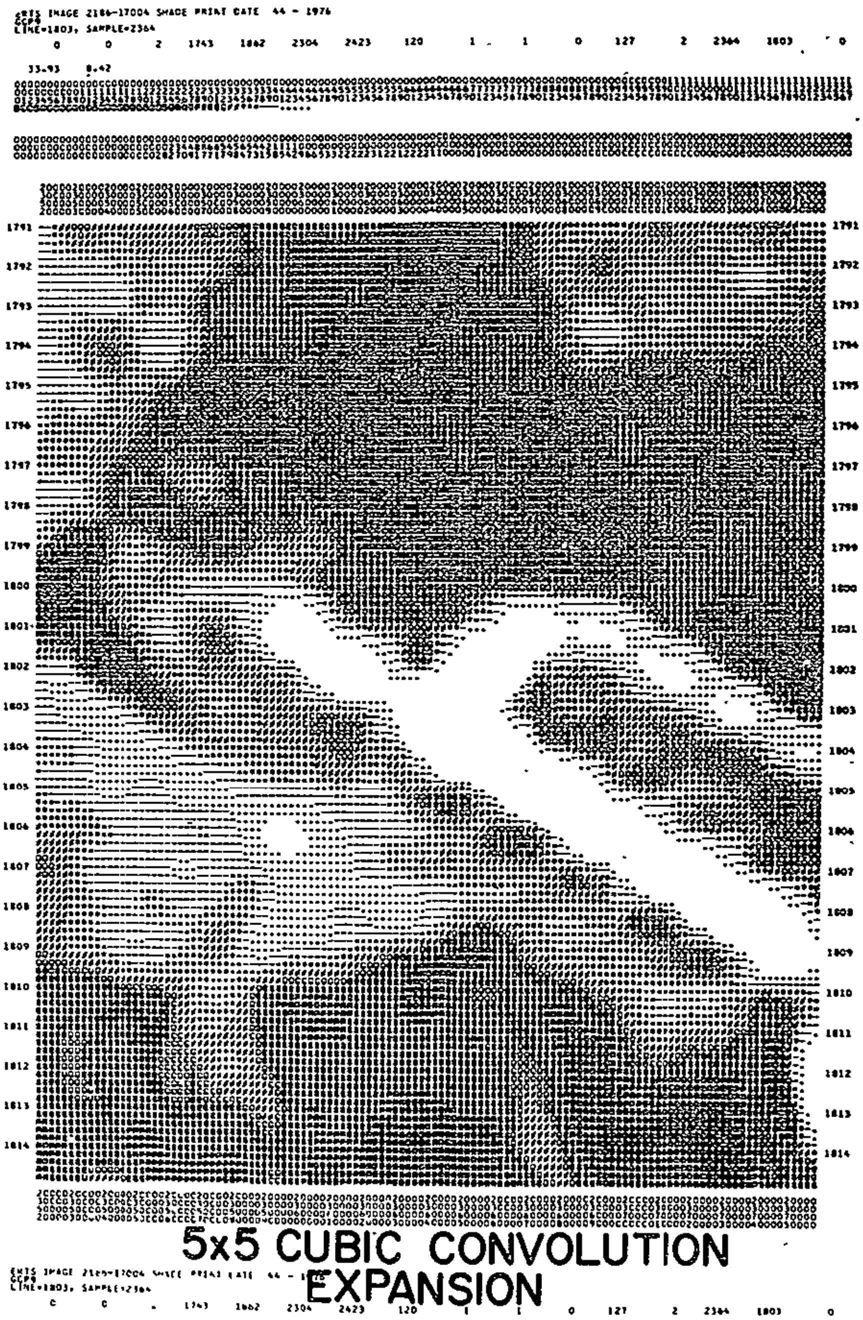

Figure 3. DIRS - generated 5x5 cubic convolution expansion expansion of runway intersection seen in Figures 1 and 2.

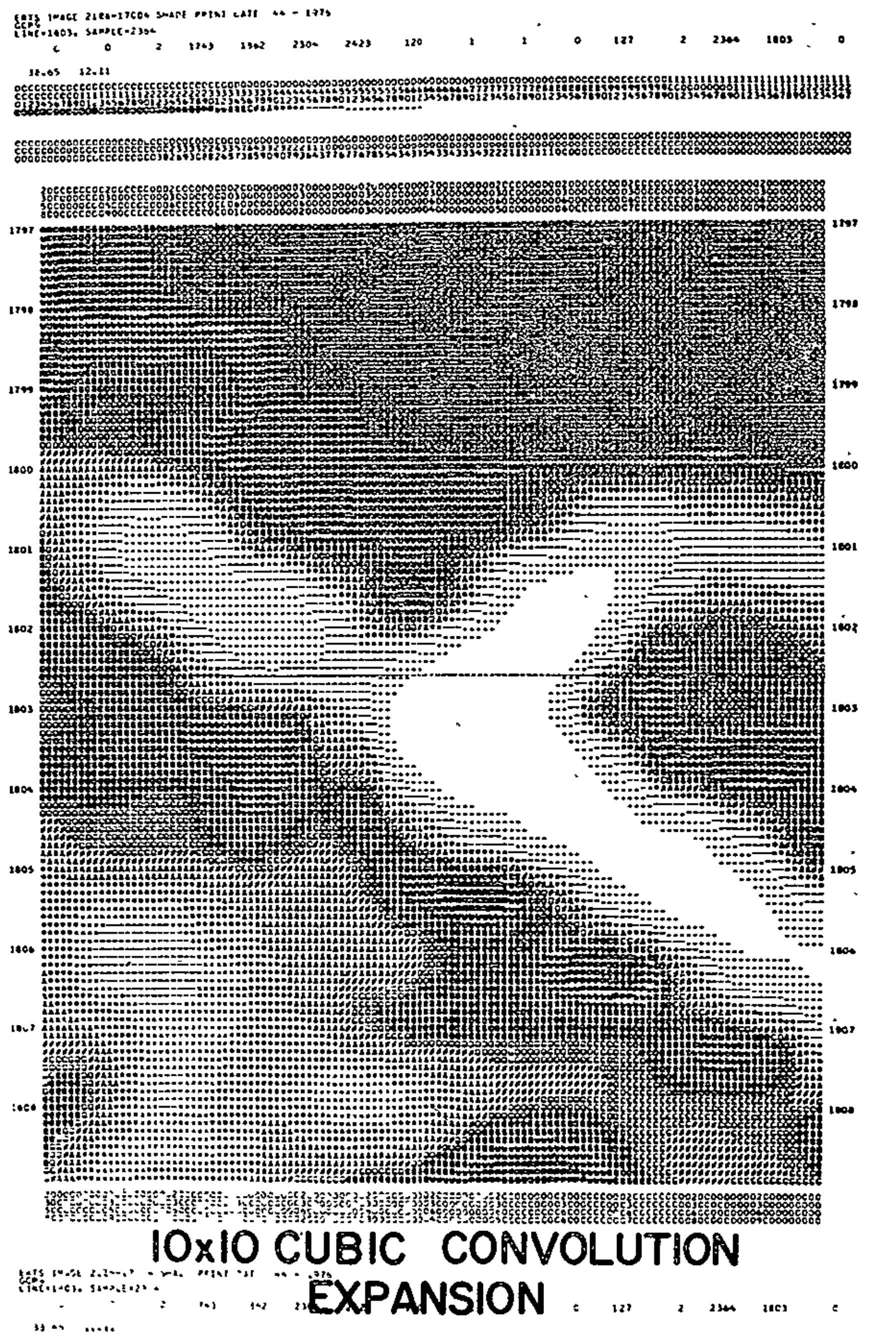

Figure 4. DIRS - generated 10x10 cubic convolution expansion of runway intersection (Figures 1 through 3). Note the MSS pixel assignments (numbers surrounding the expanded data) allow UTM coordinates to be assigned to tenths of a MSS pixel.

the rectification of an entire scene, or portions thereof. To date, GCP's have been located and assigned UTM coordinates for scene E-2186-17004. A section of the scene has been rectified. Evaluation of rectification costs and accuracies has begun.

Land Use

All participating state agencies have expressed interest in evaluating various land use data sources. GF&P and DNRD are under legislative mandate to provide resource inventories of each of the state's 16 river basins every four years. One of the most important resources in South Dakota is the land itself. Detailed information regarding its use and the spatial distribution of the various uses is considered as significant input for these four-year surveys. SPB is preparing a landuse map of the state using digital analysis of LANDSAT MSS CCT data. The Bureau is interested in evaluating the digital analyses with results obtained from other data sources.

Historically, land use information has been obtained from a variety of sources including the Conservation Needs Inventory, and Crop and Livestock Reporting Service Reports. Usually the data are not subdivided into river basins but into political subdivisions such as counties. This procedure results in estimating errors as the data are manipulated to a river basin status. Also, such data are usually several years old.

Level I land use information was interpreted for the entire 824,000 hectare Belle Fourche River Basin using 1:250,000 27 July LANDSAT color composite and MSS 7 imagery. Basic forest-cover was interpreted from 1973 winter imagery. The results of the interpretation are found in Table I.

TABLE I. LEVEL I LAND USE FOR BELLE FOURCHE RIVER BASIN

Land Use	Percent Classified	
	LANDSAT (1973,1975)	Conservation Needs Inventory (1967)
Range	68	77
Agriculture	18	14
Forest	13	7
Urban	.3	-
Surface Water	.3	-
Other	-	.8

Conservation and Needs Inventory data were obtained for Lawrence, Butte, and Meade Counties (2), the three counties comprising the Basin. By determining the percentage of each county within the Basin and multiplying this figure by the respective land use statistics for each county, CNI data were calculated as listed in Table I. Because of the eight-year difference in data and the fact that CNI statistics are not spatial, as are LANDSAT data, no direct comparisons regarding data accuracy can be made between the 1967 CNI data and the 1975 MSS data. However, as rangeland is recently being converted to agricultural production, it seems feasible to expect an increase in agricultural land and coincident reduction in rangeland during the nine years separating the data sources. The disparity between the forest measurements might be attributed to the conversion of county-based statistics to the River Basin base. This leads to a basic advantage of LANDSAT data over CNI statistics. Referring to Figures 5 and 6, the physical location of

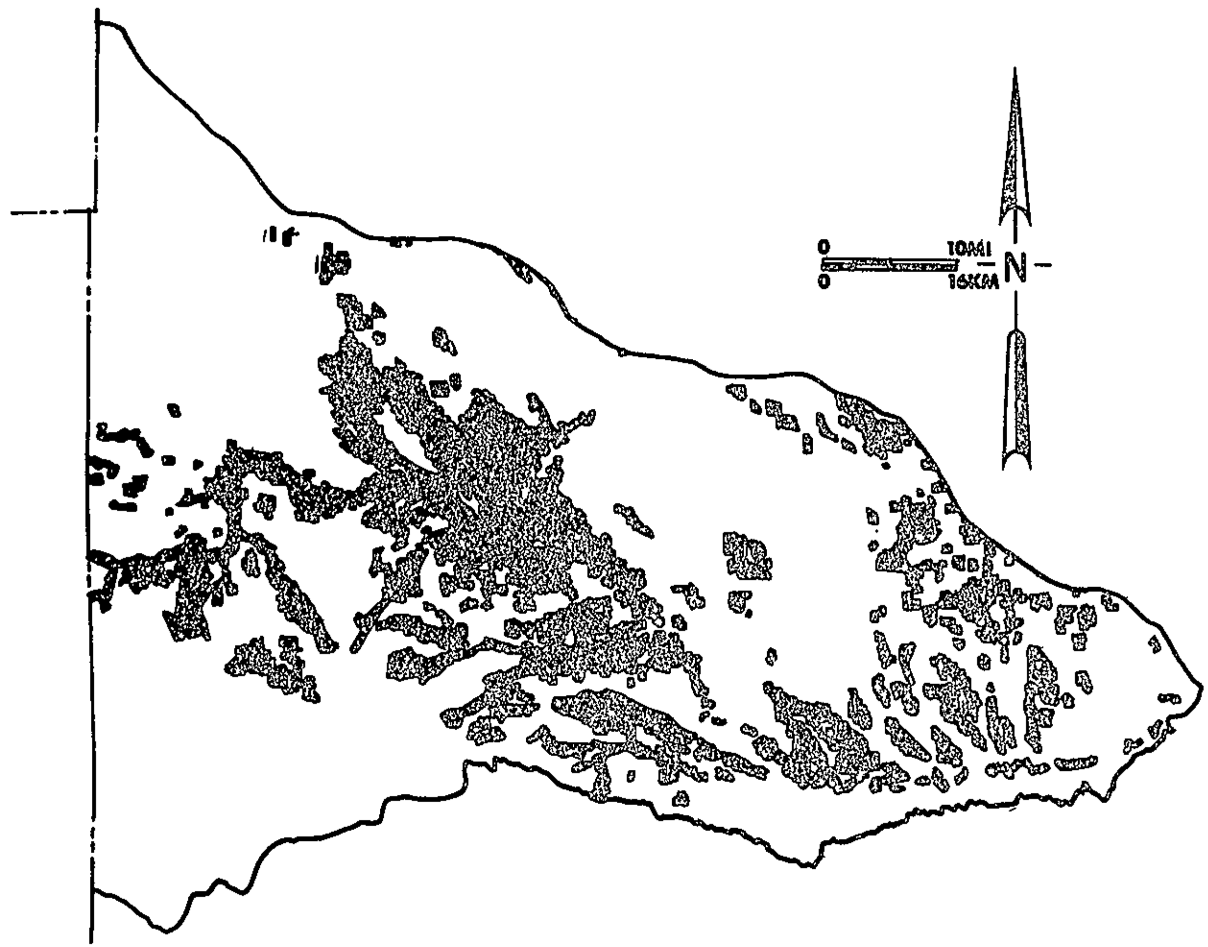

Figure 5. Agricultural land in the Belle Fourche River Basin as interpreted from 27 July 75 1:250,000 LANDSAT color composite imagery.

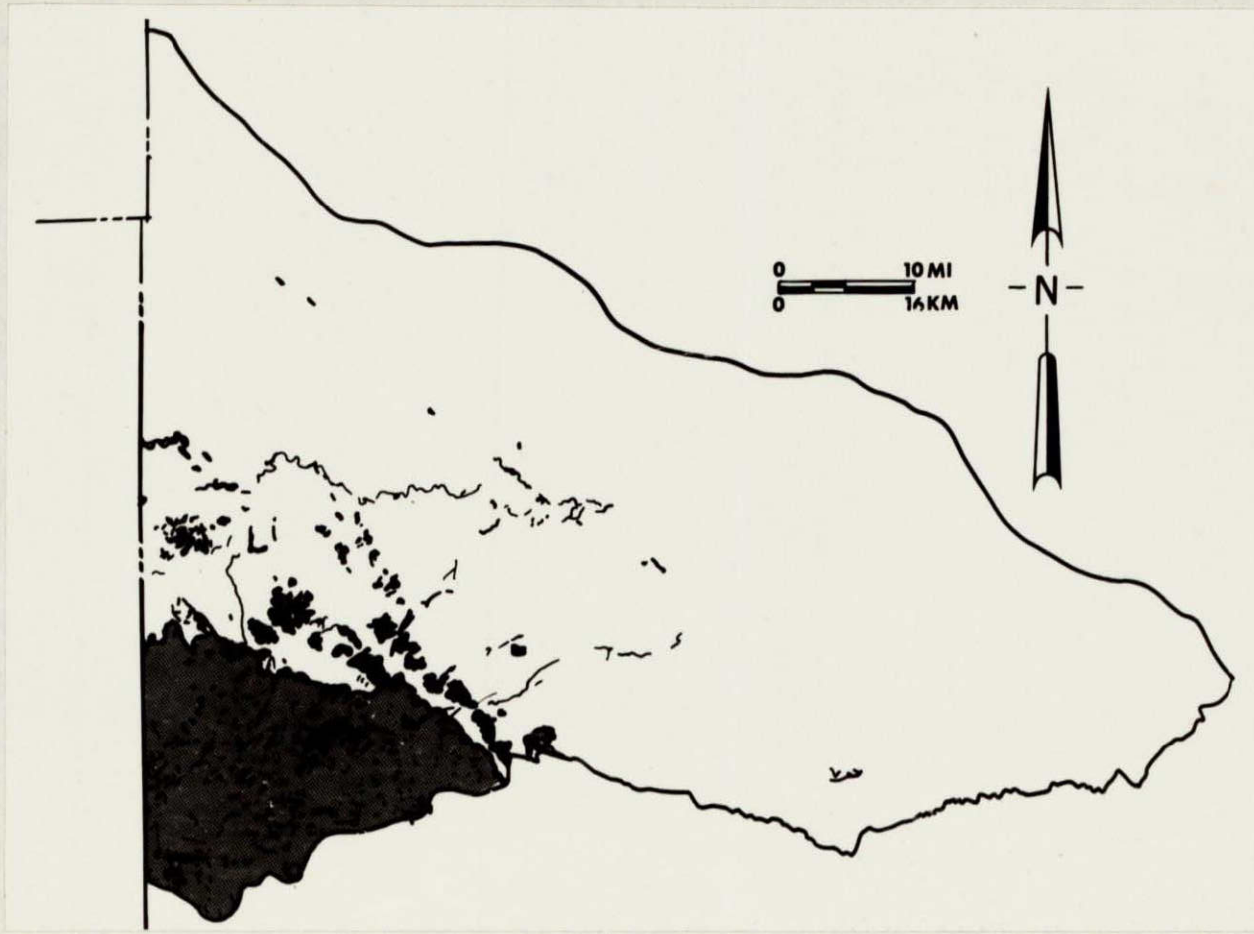

Figure 6. Forested land within the Belle Fourche River Basin as interpreted from 1973 winter LANDSAT imagery. Dark areas within the shaded (forested) area are non-forested. Dark areas outside the shaded area are forested.

the various LANDSAT-interpreted land use categories can be readily determined irrespective of any boundaries; whereas, CNI or other similar statistics produce only the data listed in Table I, after conversion from county-based statistics.

A DNRD representative prepared similar interpretations of the Basin and the results are found in Table II. Discrepancies between DNRD-interpreted

TABLE II. DNRD LEVEL I LAND USE INTERPRETATION OF BELLE FOURCHE RIVER BASIN.

Land use	Classification percentages
Range	75
Agricultural	11
Forest	13
Urban	.3
Surface Water	.3

range and agricultural lands with those percentages in Table I are attributed to the fact that this was an initial interpretation by an individual essentially untrained in photo interpretation.

To assist in evaluating the accuracies of LANDSAT interpretations, an area which contained a good selection of cloud-free LANDSAT and high-altitude imagery was selected. The site, a ten-township 230,400 acre (93,279 ha) area, is located north and east of Sturgis in the center of the basin.

Two dates of high altitude coverage are available for the site. Interpretations of color infrared transparencies produced the agricultural percentages listed in Table III.

TABLE III. HIGH ALTITUDE AIRCRAFT INTERPRETATION

Data Source	Date	Scale Interpreted	Percent Agricultural Land
High-altitude Color IR	25 Jun 75	114,506	27
High-altitude Color IR	23 Sep 75	125,880	22

The "apparent" 5 percent decrease in agricultural land during the three months separating the data is reflective of fluctuation in vegetative conditions of pasture land and rangeland. The Anderson land use classifications include pasture as a subcategory of agricultural land with rangeland a major category in itself (3). In certain areas in the June data, pasture land appears similar to other agricultural fields and is easily distinguished from rangeland. Fenced-off pasture lands are also distinctive from the surrounding apparently less profusely vegetated rangeland. As the season progresses, the vegetative cover matures and tends to dry. The drying procedure reduces the visually detectable differences between pasture and range. Certain previously recognizable pastures are all but impossible to distinguish from rangeland on the September data. For interpretation of Level 1 Agricultural land use in western South Dakota, it appears the distinction between pasture and rangeland is easier using early growing season data instead of data collected during the latter months of the growing season. Considering the fact that the Anderson classification includes pasture with agricultural lands, the June interpretation is considered to be the more accurate of the two high altitude aircraft interpretations for use in immediate interpretive comparisons.

Initial LANDSAT interpretations were conducted using the Zoom Transfer Scope (ZTS) and scene E-2186-17004 (27 July 75), as a color composite generated by the EROS Data Center. Pertinent data can be found in the upper section of Table IV. High percentages of agricultural land (as compared to values in Table III) are reflective of variations in interpretation scale, data source, and time of data collection and will be discussed below.

TABLE IV. LANDSAT COLOR COMPOSITE INTERPRETATIONS

Data Source	Date	Scale Interpreted	Percent Agricultural Land
LANDSAT Color Composite; ZTS	27 Jul 75	1:250,000	34
LANDSAT Color Composite; ZTS	27 Jul 75	1:125,000	35
LANDSAT Color Composite; Print	27 Jul 75	1:250,000	35
LANDSAT Color Composite; Print	27 Jul 75	1:250,000	15*
LANDSAT Color Composite; Print	27 Jul 75	1:125,000	30
LANDSAT Color Composite; Print	12 Jun 75	1:125,000	27
LANDSAT Color Composite; Print	27 Jul 75	1:125,000	27
LANDSAT Color Composite; Print	1 Sep 75	1:125,000	22

* DNRD interpretation

The Zoom Transfer Scope (ZTS) interpretations were time consuming as relating to time required to register the image to a base map. At 1:250,000 four townships can be seen through the scope. For the 130-township River Basin, approximately thirty registrations would be required. Another difficulty encountered using data interpreted from the ZTS system is spatial accuracy. As interpretations approached the edges of the field of view and then were re-registered to the next interpretive area,

adjoining interpretation lines did not consistently allign with one another. Errors at these match lines were consistently between .25 and .5 scale miles (.4-.8 km). This specific problem was reduced somewhat at the larger 1:125,000 scale but, instead of interpreting four townships in a single registration set up, a single township could be comfortably seen through the ZTS field of view. That would require 130 separate registrations to interpret the basin. Also, at 1:125,000 there was a problem of registering MSS data to base maps. For certain sections of western South Dakota, there are areas where no map-related landmarks are visible in a LANDSAT image for the ZTS field of view. These areas make accurate registration of a single township difficult and time-consuming. Based on these experiences, use of the ZTS/transparency combination is not recommended as a sole interpretive device for use by South Dakota state agency personnel in interpreting western South Dakota LANDSAT imagery.

Color composite print interpretations of the July image produced the data listed in the center section of Table IV. In two out of the three interpretations, the percent agricultural land was greater than the base data of Table III. The DNRD interpretation is the exception for reasons previously discussed. The disparity between results of relatively untrained DNRD interpreters points to a need for basic photo-interpretation training. In other words, a department should not expect untrained personnel to immediately possess the ability to interpret land use data from LANDSAT imagery. Of the data sets, the 125,000 scale produced the percentage nearest the 27 percent as interpreted from high altitude aircraft imagery. The color composite used for the ZTS and

these three print interpretations was a standard color composite as prepared by the EROS Data Center. Interpretations of these data were consistently in the thirty percent agricultural range.

As mentioned above, 1:125,000 print interpretations produced the most acceptable results so RSI produced color composites were printed at 1:125,000. In general, the RSI color composites were in better registration and slightly "sharper" than EROS color composites. The EROS color composite did contain higher contrasts, brighter colors, and was definitely more pleasing to the eye. However, interpretation of the RSI data produced percentages, lower section of Table IV, which are quite compatible with the interpreted high altitude aircraft data. As can be seen, the 12 June and 27 July LANDSAT interpretation percentages are in agreement with the late June high-altitude data. The 1 September interpretation percentage is the same as that obtained from late September high-altitude data. However, overall percentages do not completely reflect interpretation reliability. Spatial definition is an important factor and must be studied. Such investigations will be accomplished during the course of this project.

Interpretations for three of the data sets listed in Table IV are found in Figures 7, 8, and 9. Note areas A and B on the high altitude interpretation, Figure 7. Area A is a strip of rangeland passing through an agricultural area. Area B is intermittently spaced agricultural land along the Belle Fourche River. The 1:250,000 ZTS interpretation, Figure 8, reflects little problem in interpreting the major agricultural areas. However, detailed information was not consistently interpreted. The rangeland at A was included as agricultural land and the small fields surrounding B were grouped into fewer, larger agricultural areas. Inter-

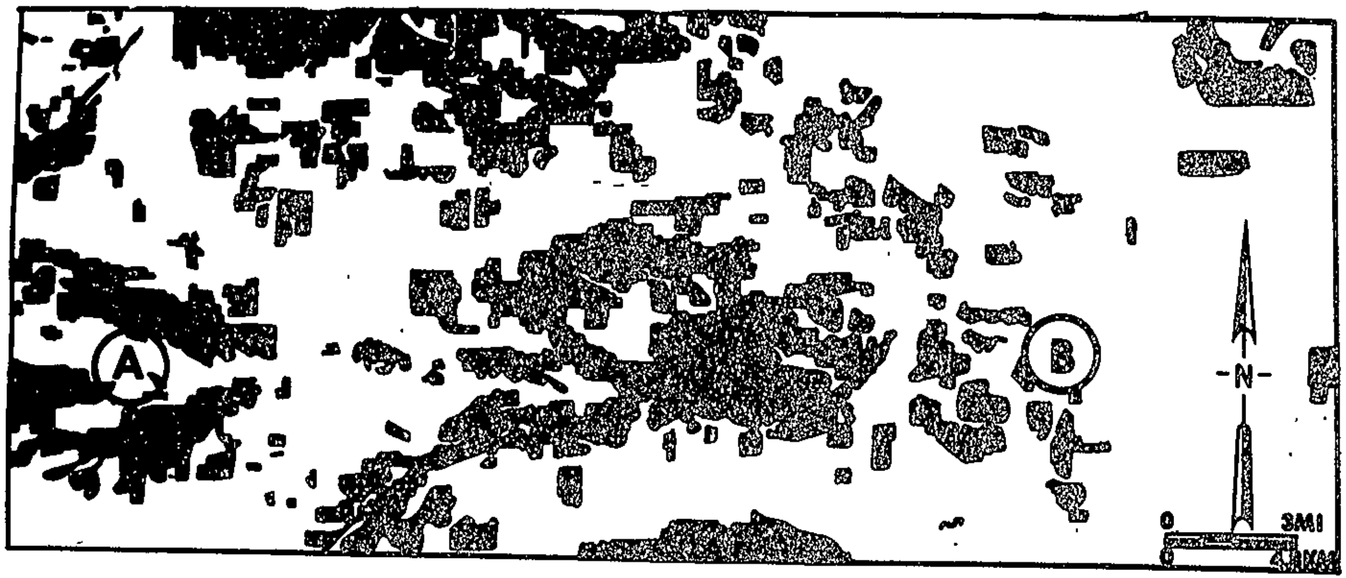

Figure 7. June 1975 high altitude aircraft color infrared transparency interpretation of agricultural land for a ten-township test area. Area "A" is rangeland passing through an agricultural area; area "B" is intermittently spaced agricultural land along the Belle Fourche River. Interpretation scale : 1:115,000.

Figure 8. Agricultural land interpreted from a 27 July 75 LANDSAT color composite transparency. Image was registered to 1:250,000 base map using a Zoom Transfer Scope. Detailed information is not consistently interpreted. Rangeland at "A" was included as agricultural land and the small fields surrounding "B" were grouped into fewer, larger agricultural areas.

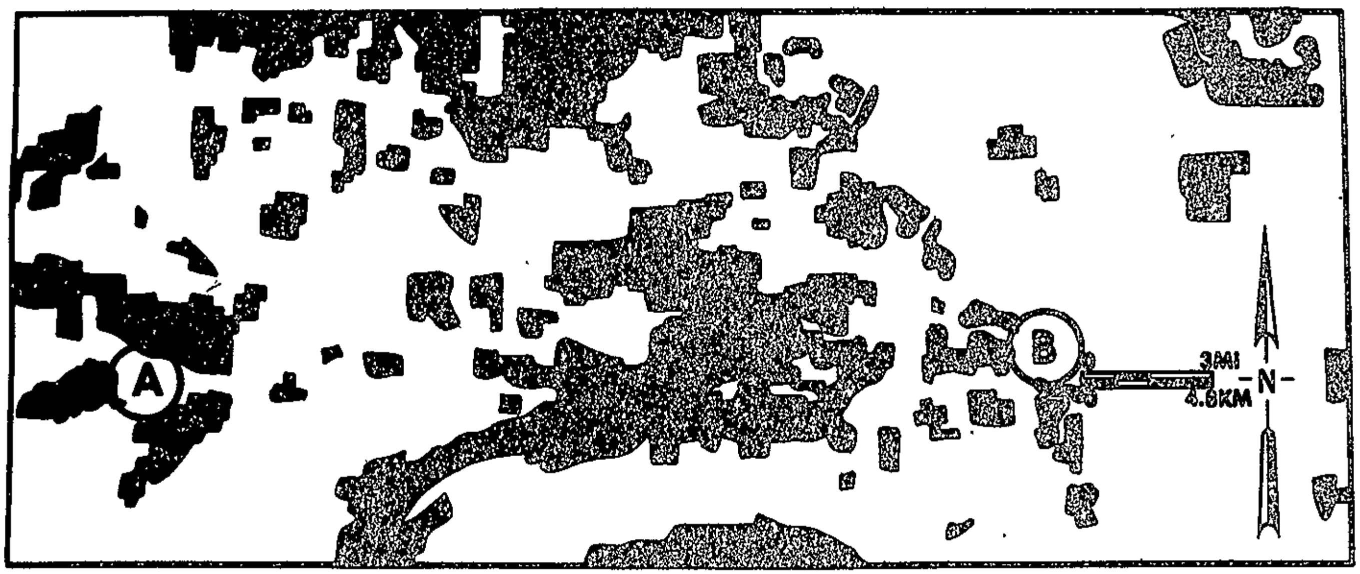

Figure 9. Agricultural land interpretation of a 1:125,000 27 July 75 LANDSAT Color composite print. Rangeland at "A" is identified and the field groupings at "B" have not been coalesced into larger units to the extent of the 1:250,000 interpretation of Figure 8.

pretation of the 1:125,000 RSI color composite is seen in Figure 9. Rangeland at A is correctly identified and the field groupings at B have not been coalesced into larger units to the extent of the 1:250,000 interpretations. Referring to Table IV, the basic cause for LANDSAT-interpreted agricultural lands being of greater percentage than high altitude aircraft interpretations seems to rest on the aggregation of rangeland into agricultural areas. This appears to be alleviated by proper selection of data date and scale of interpretation. In other words, for visual interpretation of LANDSAT color composites, MSS data collected in the early growing season and printed to a scale of 1:125,000 is considered a prime data source.

Individual bands of black and white LANDSAT data are less expensive than a color composite, and black and white prints are less costly than color. To evaluate the potential of visually interpreting land use data from the individual black and white data products, a variety of prints have been interpreted for agricultural land. Interpretation results are found in Table V. All available cloud-free imagery throughout the growing season is to be interpreted to allow comparisons with color composite and aircraft data interpretations. This will include May, June, July, August and September data. The August and September data remain to be interpreted. MSS 5 and 7 were selected because of their inherent benefits in observing vegetation, i.e. MSS 5 filtered red and MSS 7 in near infrared. In general, MSS 7 interpretations produced a smaller percentage of agricultural land than did MSS 5. In two of the three cases, MSS 5 interpretations were less than the data base. What could be happening is that the individual bands are recording selective reflected energy from the various land covers. When viewed

TABLE V. LANDSAT BLACK AND WHITE INTERPRETATIONS

Data Source	Date	Scale Interpreted	Percent Agricultural Land
LANDSAT MSS 5	24 May	1:125,000	23
LANDSAT MSS 7	24 May	1:125,000	13
LANDSAT MSS 5 & 7	24 May	1:125,000	28
LANDSAT MSS 5	12 June	1:125,000	28
LANDSAT MSS 7	12 June	1:125,000	21
LANDSAT MSS 5 & 7	12 June	1:125,000	36
LANDSAT MSS 5	27 July	1:125,000	20
LANDSAT MSS 7	27 July	1:125,000	20
LANDSAT MSS 5 & 7	27 July	1:125,000	29

on a single MSS band, certain vegetated agricultural areas are not easily recognizable. It was then assumed that by overlaying the interpretations of MSS 5 and MSS 7 and preparing a new combined interpretation, improved maps would result. The overlay procedure was biased toward agricultural land. That is, if agricultural land was interpreted on either MSS 5 or MSS 7 or both, it was outlined on the new interpretation. However, if rangeland was to be included on the new map, it had to be present on both MSS 5 and MSS 7 interpretations. Based solely on the percentages of Table V, the combination interpretations for May and July, and June MSS 5 appear worthy of further investigation regarding spatial reliability and cost effectiveness.

Surface Water

Analysis of interpretive scales and data sources was initiated to provide a basis for recommendations regarding LANDSAT as a surface water inventory tool. While surface water is a category in Level I land use, it is handled separately here. To be classified in a Level I land use classification, the surface area must equal or exceed 40 acres (16 ha). In western South Dakota there are numerous bodies of water which are considerably less than 16 hectares. The number and distribution of these smaller bodies of water are important in evaluating the general water (and soil moisture) conditions throughout the basin. The small water bodies are also important to western South Dakota fisheries management, wildlife and livestock production. To inventory only 16 ha and greater surface water bodies, as specified in Level I Land Use, would place serious restrictions on the reliability and usefulness of the surface water inventory. For these reasons, surface water is separated from the Level I Land Use category and the surface water inventory capabilities of LANDSAT are separately investigated in detail.

Initial work has centered on a physical accounting of the numbers of bodies of water. Further studies will address the ability to determine surface areas. Basin-wide surface water inventories have been conducted at a scale of 1:250,000 using MSS 7 transparencies and the ZTS and black and white MSS 7 prints. The data from the ZTS were coded into a data base (4). DNRD prepared two basin surface water interpretations one of which is seen as Figure 10. Outlined in Figure 10 is the same 10-township area employed in the previously discussed land use interpretations. This area is also being used for more detailed surface water interpretations because of the available selection of cloud-free data.

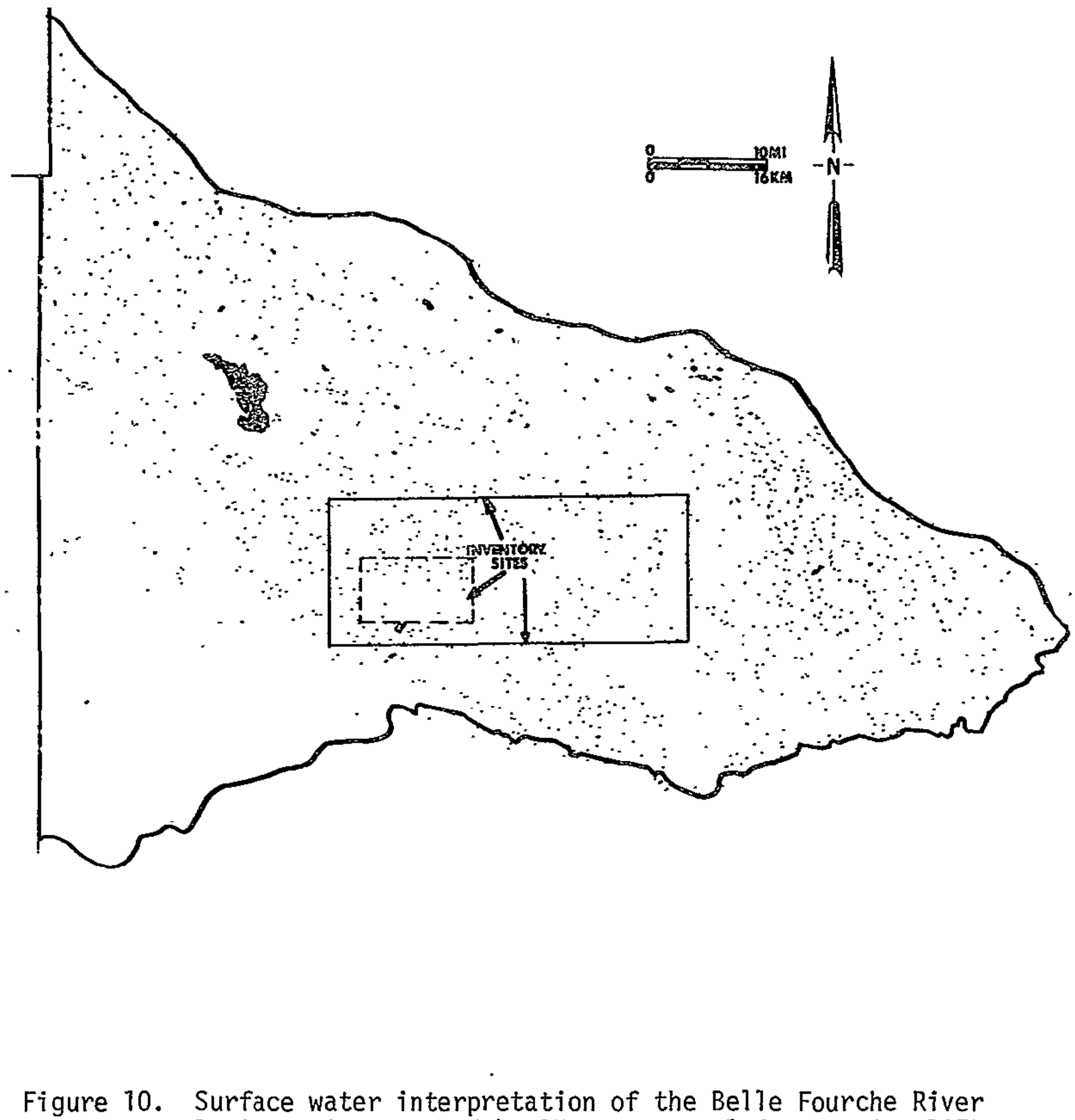

Figure 10. Surface water interpretation of the Belle Fourche River Basin as interpreted by DNRD personnel from spring 1975 LANDSAT MSS 7 imagery. Visual print interpretation was conducted at 1:250,000. The larger rectangular area is a ten-township site interpreted for water bodies from a variety of data sources. The smaller outlined area was interpreted with more detailed evaluation of LANDSAT inventory capabilities.

The interpretations for the ten-township area are listed in Table VI. Using the June color infrared high-altitude interpretation as a comparative base the other interpretations are offered for review. Both the June and September high altitude color infrared film data sources were interpreted from the original film transparency on a light table. The interpretation of September high-altitude imagery resulted in a comparative inventory value (percent of June aircraft inventory) less than the earlier aircraft data. Quite possibly this is due to the dynamic conditions of surface water and the general reductions of surface water areas associated with late summer/early fall. The comparativeinventory value for all LANDSAT interpretations were less than the June and September aircraft interpretations. The average comparative value of the three 1:250,000 12 June interpretations is .45. Enlargement of the 12 June data to 1:125,000 allowed for a substantial increase of this figure to .62 indicating advantage to using the larger scale. Interpretation of seasonal data, 27 July, indicated fewer bodies of water were observable. This is, again, attributed to the intermittent nature of certain ponds. While general conclusions regarding recommended scales and data dates for interpretation can be inferred from this review, a more detailed analysis would provide specific information on which to base recommendations.

The detailed analysis was conducted over the smaller area outlined in Figure 10. Table VII contains the results of the more detailed study. The comparative inventory values referred to above were measures of the ability of a variety of data sources to map all surface water (as interpreted from a comparative data base), irrespective of waterbody size. As the basic pixel resolution cell for LANDSAT MSS is 1.1 acres (.45 ha), it was assumed that an interpretation categorizing surface

TABLE VI. SURFACE WATER INTERPRETATIONS

Data Source	Date	Scale Interpreted	No. Water Bodies	Comparative Inventory Value
High-altitude Color IR Transparency	25 Jun 75	1:114,506	652	1.00
High-altitude Color IR Transparency	23 Sep 75	1:125,880	591	.91
LANDSAT MSS 7; ZTS	12 Jun 75	1:250,000	488	.75
LANDSAT MSS 7; Print	12 Jun 75	1:250,000	273	.42
LANDSAT MSS 7; Print	12 Jun 75	1:250,000	343	.53
LANDSAT MSS 7; Print	12 Jun 75	1:250,000	266	.41
LANDSAT MSS 7; Print	24 May 75	1:125,000	380	.58
LANDSAT MSS 7; Print	12 Jun 75	1:125,000	402	.62
LANDSAT MSS 7; Print	27 Jul 75	1:125,000	222	.34

TABLE VII. DETAILED SURFACE WATER ANALYSIS

Data Source	Date	Scale	Total No. Water Bodies	Percent of total which is not water	Percent of base data correctly interpreted	
					≤1.1 acre (.45 ha)	>1.1 acre (.45 ha)
High-altitude black and white IR, print[1]	25 Jun 75	1: 24,000	146	0	100 Base Data	100
High-altitude color IR trans[2]	25 Jun 75	1:114,506	113	8	49	98
LANDSAT MSS 7; ZTS	12 Jun 75	1:250,000	90	36	5	82
LANDSAT MSS 7; Print (GF&P)	12 Jun 75	1:250,000	54	13	3	70
LANDSAT MSS 7: Print (DNRD)	12 Jun 75	1:250,000	58	14	4	71
LANDSAT MSS 7; Print (DNRD)	12 Jun 75	1:250,000	64	11	4	83
LANDSAT MSS 7; Print	24 May 75	1:125,000	74	11	21	74
LANDSAT MSS 7; Print	12 Jun 75	1:125,000	86	26	11	83
LANDSAT MSS 7; Print	27 Jul 75	1:125,000	38	8	1	52
USGS Quadrangle Map	1953	1: 24,000	119	24	55	70

[1] 80 mm focal length Hasselblad

[2] 6" focal length Zeiss

water into those equal to or less than the area of a basic cell and those greater than a basic cell would be beneficial in analyzing the inventory capabilities of visual LANDSAT interpretations. Base data for this detailed surface water study was interpreted from black and white near infrared prints as enlarged from high altitude 70 mm film (80 mm focal length Hasselblad). The interpretation resulted in 146 individual water bodies within this smaller test site. Of the 146 total water bodies on this more detailed base interpretation, over half were equal to or less than the basic LANDSAT pixel resolution. The total area of these smaller water bodies was 52 acres (21 ha). Whereas the area for the sixty-six larger classified water bodies was 182 acres (73.7 ha). In other words the larger (over .45 hectare) water bodies numerically account for 45 percent of the total but 78 percent of the total surface area.

High altitude color infrared transparency data were interpreted directly on a light table. Less than half of the smaller water bodies were correctly interpreted. Enlargement of data might have improved interpretation of the smaller water bodies.

Comparison of LANDSAT interpretations with 1:24,000 Quadrangle maps reveals an important observation. In all but one LANDSAT interpretation (late July; for reasons discussed above) the larger water bodies were more currently mapped using MSS 7 imagery than could be accomplished using existing maps of the area. Figure 11 is a reproduction of the >1.1 acre (.45 ha) base high altitude data. Note the areas circled and labeled A through E. These five water bodies account for 27 acres (10.9 ha) of surface water. Figure 12, the 24 May MSS 7 interpretation, indicates these five water bodies have been inventoried using LANDSAT

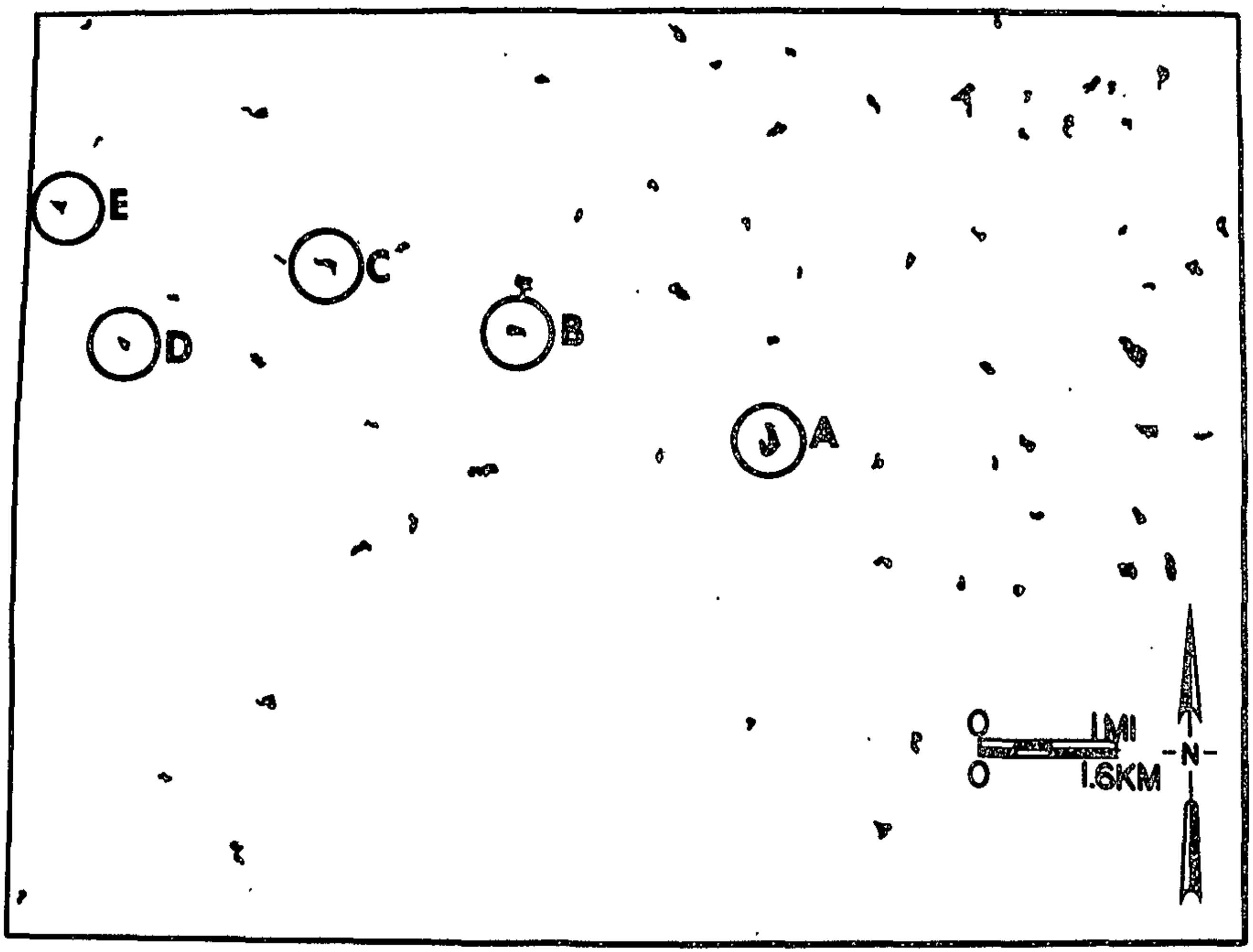

Figure 11. Reproduction of the >1.1 acre (.45 ha) high altitude base surface water data. Note the areas circled and labeled "A" through "E". Scale of interpretation: 1:24,000; date of data collection: 25 June 1975.

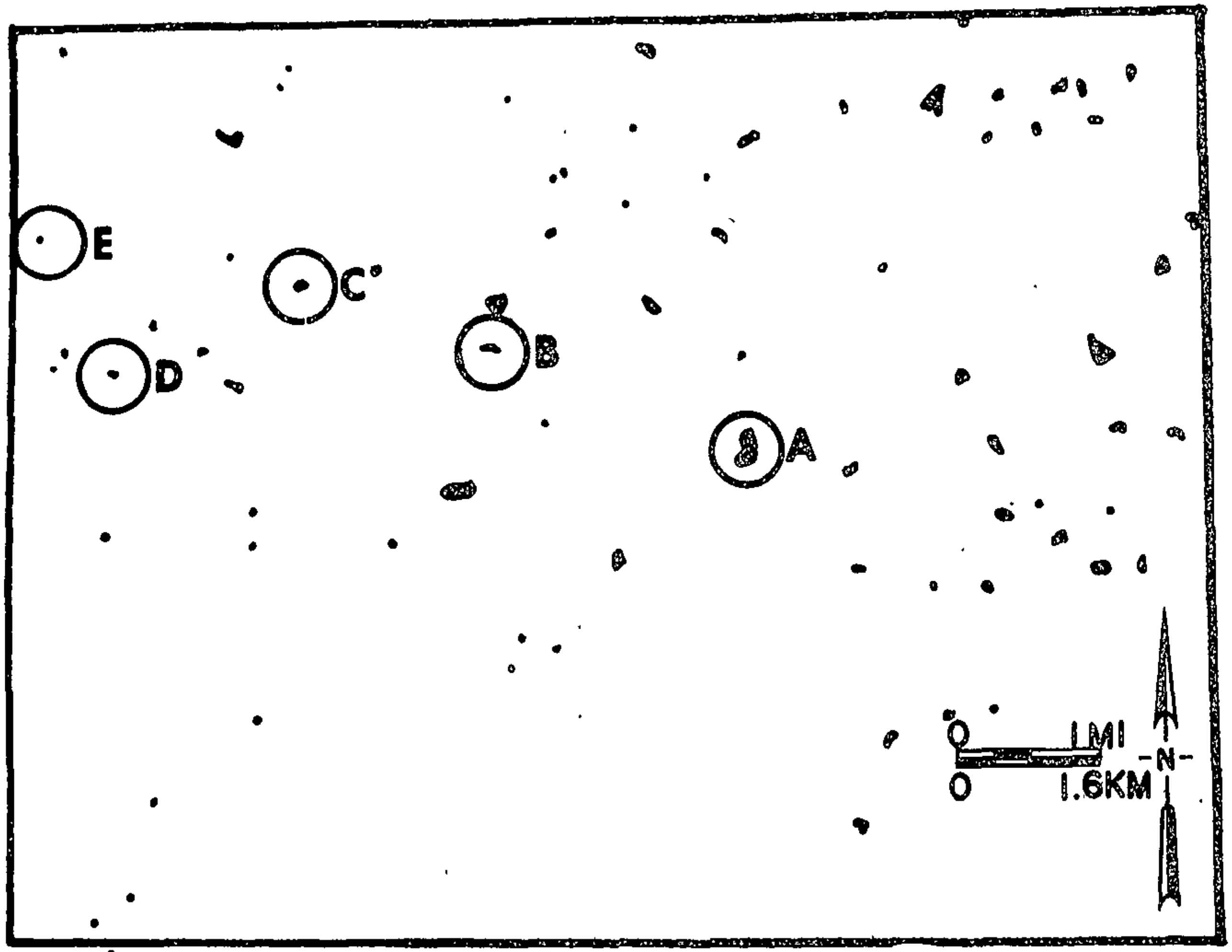

Figure 12. Reproduction of the 24 May 1975 MSS 7 surface water interpretation. Water bodies "A" through "E" have been inventoried on this 1:125,000 print interpretation.

visual interpretations. Later MSS 7 data (July 27), Figure 13, reveal the dynamic physical properties of certain water bodies. In general, the interpreted area appears drier at this time of year, as compared to early in summer. In particular, water bodies C and D have disappeared. In other words, both the year and time of year of data collection are important in the interpretation of the most current surface water inventories. For a base inventory, spring and early summer data is preferred over late summer or early fall data. A wet year would be preferred to a dry year.

The USGS Quadrangle map, as interpreted for surface water, is seen in Figure 14. Note the absence of all five designated water bodies. Again, the comparative accuracy of interpreting greater than .45 hectare water bodies from the 1953 1:24,000 USGS quadrangle maps was equalled or exceeded in all but the late July LANDSAT interpretation. Of the three interpretations submitted by state agencies, one was the highest overall in comparative interpretation of the over .45 hectare category and the other two agency interpretations were equal to or better than the Quadrangle map interpretation. The three interpretations were essentially initial attempts by participating state agency personnel at photo interpretation of surface water from LANDSAT data.

The importance of these statements can be reinforced when one realizes that 43 percent of the available 1:24,000 Quadrangle maps for South Dakota are 20 years old or older, and that 42 percent of the state remains unmapped at that scale. Fully 73 percent of South Dakota is either unmapped at 1:24,000, or is mapped by 15 year old or older maps similar to those used in the above illustration (5). Even if the maps were available for the entire state, the cost of the approximately 250 1:24,000

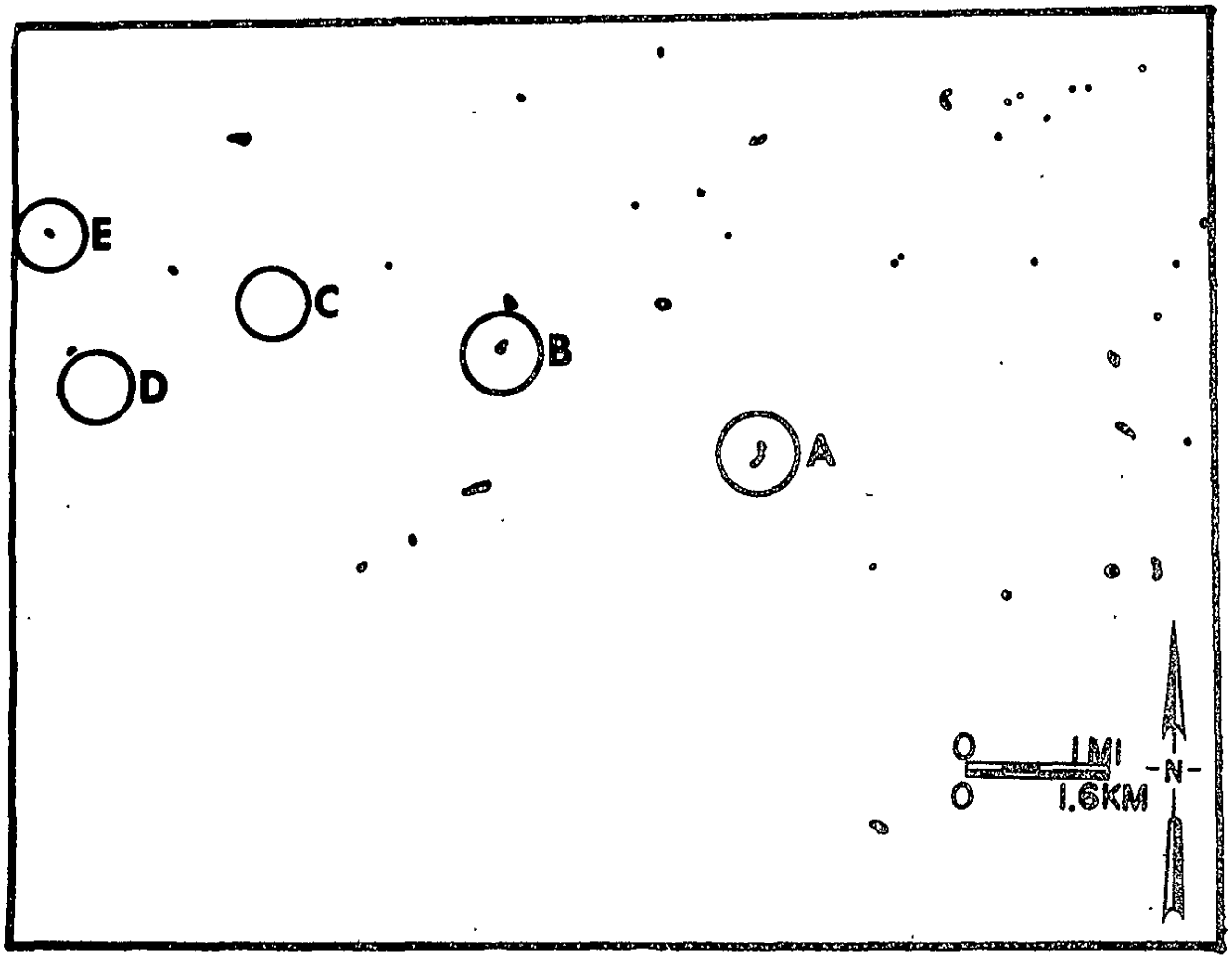

Figure 13. Reproduction of the 27 July 1975 MSS 7 surface water interpretation reveals the apparent dynamic physical properties of certain water bodies. In general, the interpreted area appears drier, as compared to the May interpretation of Figure 12. In particular, bodies "C" and "D" have apparently disappeared. Interpretation scale : 1:125,000.

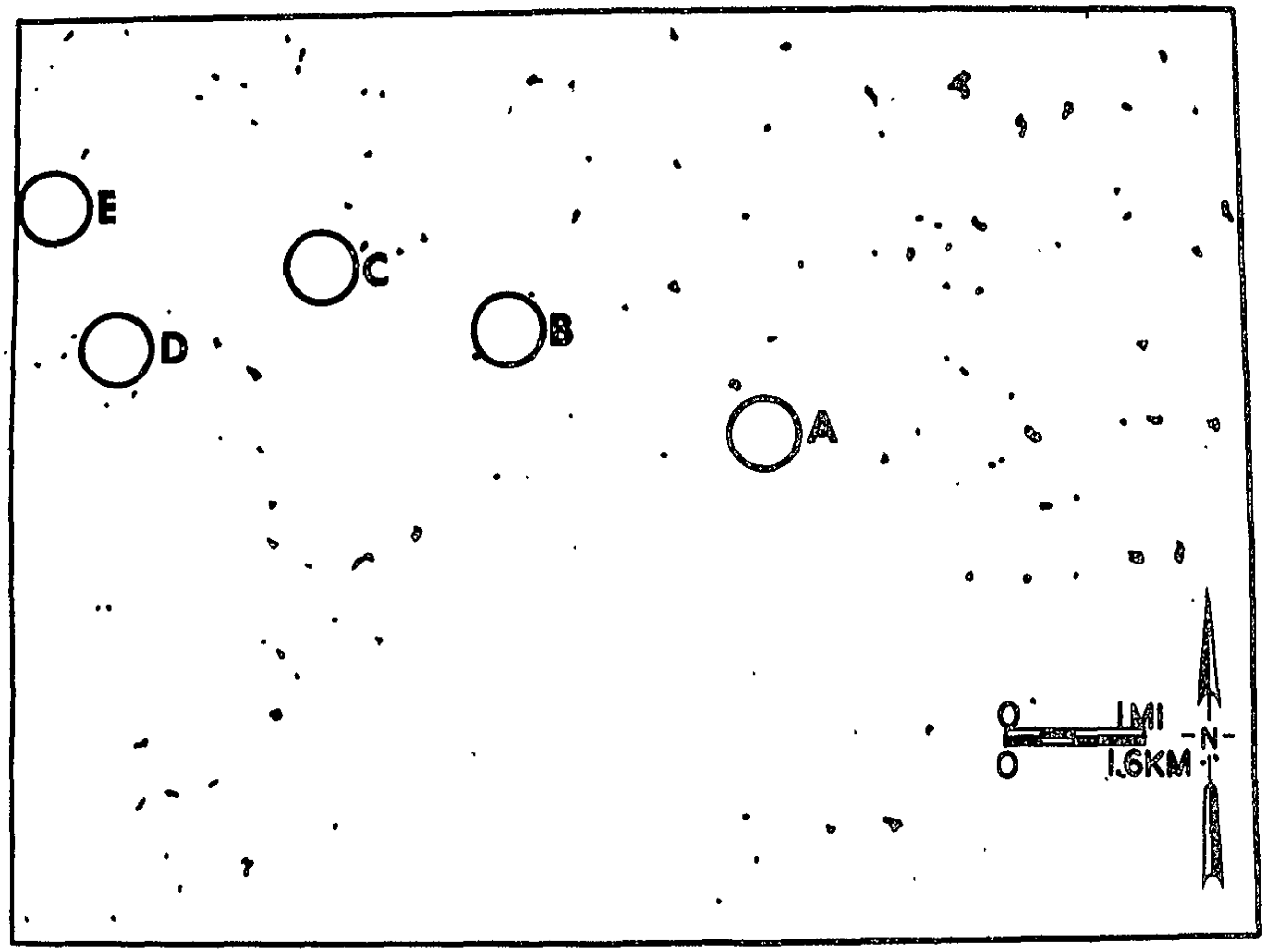

Figure 14. Reproduction of the 1953 1:24,000 USGS Quadrangle map as interpreted for surface water. Note the absence of all five designated water bodies.

maps required to map the area covered on a $5 LANDSAT MSS 7 frame would be about $200 (6). Even then, if the data used in the map production were collected in late summer or a dry year, the surface water data would probably not be as current as would be possible with more timely LANDSAT data.

An accurate inventory of surface water should be conducted with all available input, giving proper consideration to date(s) of collection. Updating of data contained on 1:24,000 USGS Quadrangle maps using MSS 7 interpretations, and use of LANDSAT data exclusively in areas devoid of detailed maps would appear to be a basic recommendation to be reached regarding surface water inventories.

Aspen

An aspen resource inventory of the Black Hills area has assumed added importance to GF&P personnel. The Department was involved in a study which indicated pulverized aspen to be a good cattle feed. Black Hills aspen groves may now become an asset rather than the liability of the past. Potential development includes planned harvesting of aspen for use as a feed supplement. Development of a method for locating and monitoring aspen groves resulted in GF&P initiation of this aspect of the project.

An area of representative forest types was located using high altitude aircraft imagery. Visual interpretation of 27 July 75 color composite LANDSAT data indicated visual aspen interpretation of July MSS data to be impractical (4).

Digital analysis of the 27 July data was considered as a possible data source. CCT for LANDSAT scene 2186-17004 (27 July 75) was obtained

through EROS. A representative area was selected from high altitude aircraft imagery and the approximate CCT pixel coordinates for the sample area were determined. Initially MSS 7 data were removed from the tape and displayed via the line printer. Comparison of the raw MSS 7 data with aircraft imagery was conducted in an attempt to manually select CCT reflectance levels which would correspond to grass, pine and aspen. A level was selected for each of the three classifications and a line-printer map was generated. Visual inspection of the level-sliced MSS 7 data revealed that excessive amounts of grass and thin pine were being misclassified as aspen.

An RSI program called "K-class" was then employed to determine if a statistical relationship could be developed using all four MSS bands and selected training areas. Training areas of pine, thin pine, aspen, and grass were designated from high-altitude aircraft imagery. Mixed aspen pine was designated to be classed as pine because such aspen would not be easily harvested and the classification of such aspen would not be very useful. The area included sufficient samples to allow K-class to classify the data into three basic categories: pine, aspen, and grass. K-class processing of the data produced an apparently more reliable classification with less confusion between thin pine, grasslands, and aspen.

Figure 15 is the aspen interpretation of high altitude color infrared film for the area digitally analyzed from LANDSAT CCT'S. Notice that not only are there a few large aspen stands but also numerous smaller stands throughout the area. The stand marked "A" can also be seen correctly identified in the K-class generated map of Figure 16. Here again, one can see a few large aspen stands and numerous smaller stands throughout

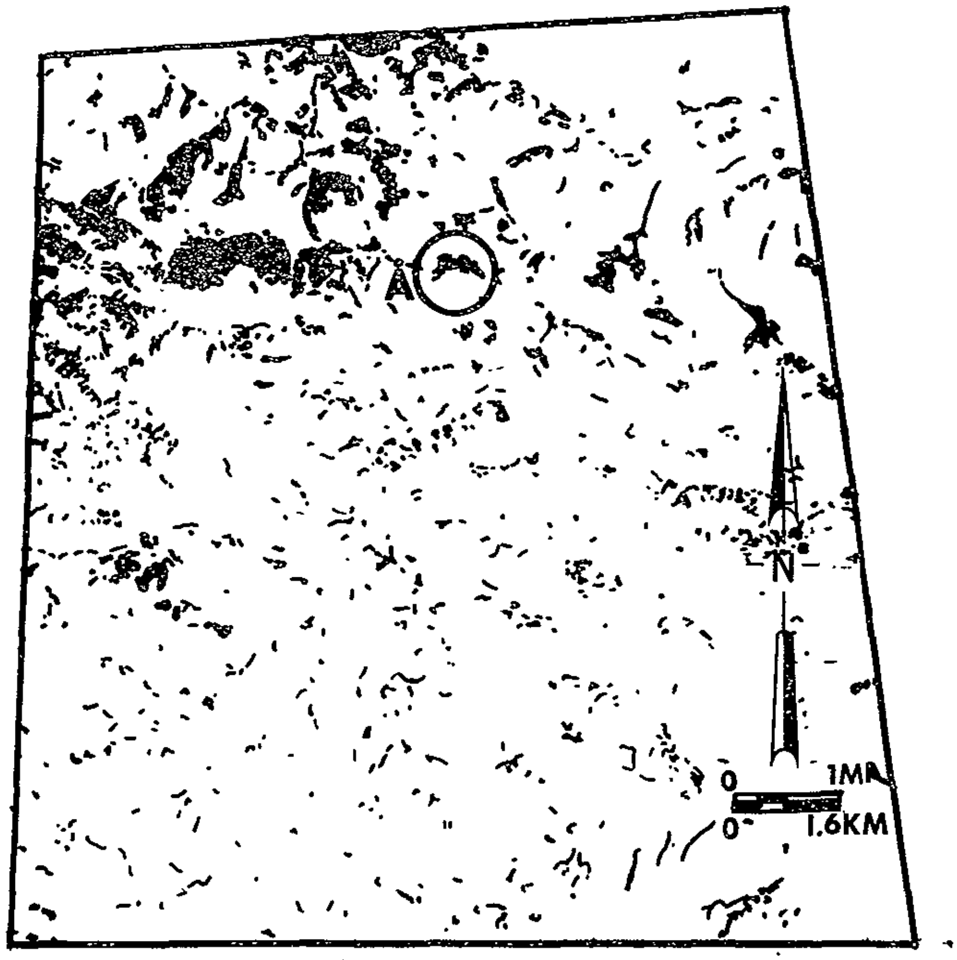

Figure 15. Aspen interpretation of high altitude color infrared (June 1975) imagery. Interpretation scale was 1:32,000. The outlined interpreted area corresponds to the area digitally analyzed from LANDSAT CCT data. Note the aspen stand marked "A".

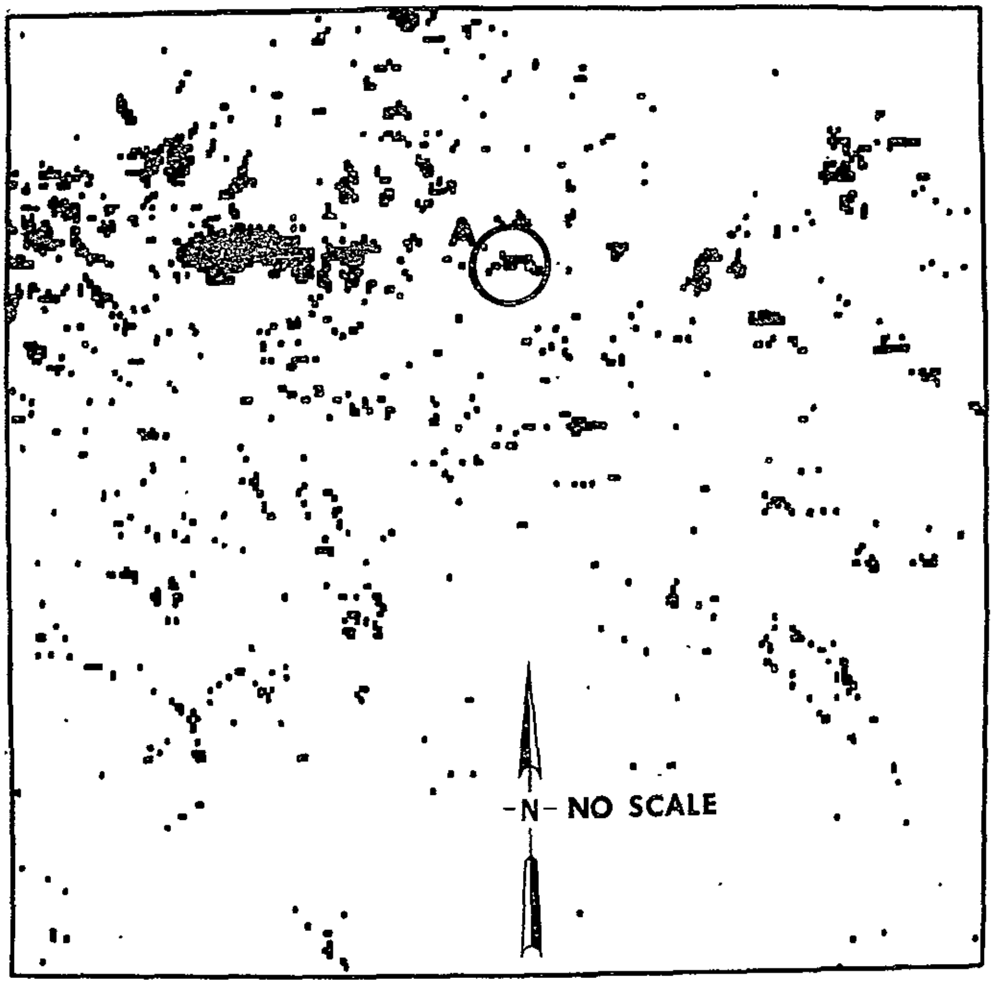

Figure 16. K-class aspen interpretation of 27 July 1975 LANDSAT CCT data. Note stand "A" has been correctly identified

the forest. The map of Figure 16 is unrectified LANDSAT data which makes spatial accuracy evaluation difficult. The DIRS program in conjunction with K-class will be employed for detailed analysis of the LANDSAT-based map.

Of the total area surveyed, the aircraft map produced a total of 2,578 acres (1044 ha) of aspen. The K-class program, processing July CCT data interpreted 1,667 acres (675 ha) of aspen. Mid-summer is not an optimum time for collection of data to be used in interpreting as the differences between grassland and aspen are relatively subtle. Such conclusions were also reported by Driscoll (7). The July 27 data was processed because of its availability and to test the procedures involved. Comparison of the June and September high altitude aircraft imagery show that while aspen are interpretable from both, the distinction between aspen and grass is much more pronounced in the September data than in the June data. In September, the grasses have apparently dried and reflect considerably less infrared radiation than was the case in June. However, the aspen leaves are still as "green" as they were in June. The distinction between grass and aspen is, therefore, enhanced. A CCT for LANDSAT scene 2222-16595 (1 Sep 75) has been procured and the K-class analysis will be performed on the data contained therein.

GF&P could obtain U.S. Forest Service maps over certain areas of the Black Hills. Figure 17 is a high-altitude aircraft interpretation of aspen for township T4NR5E. Again, the interpreted aspen stand referred to as "A" in Figures 15 and 16 can be seen, along with numerous smaller stands. A U.S. Forest Service map of T4NR5E was obtained and the aspen interpreted from the map is seen in Figure 17. Notice the absence of stand "A". Also notice the absence of the smaller stands of aspen.

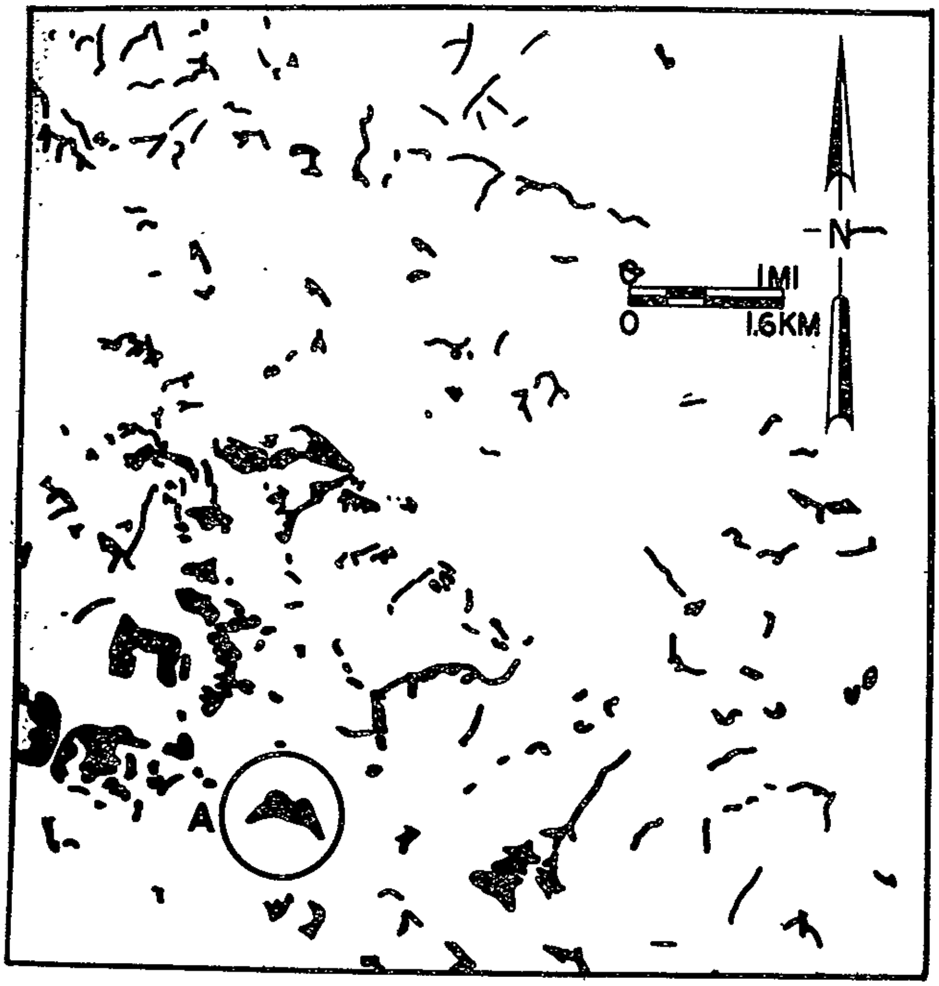

Figure 17. High altitude color infrared (June 1975) imagery of township T4NR5E as interpreted for aspen. Note stand "A" (same as that in Figures 15 and 16) and the numerous small aspen stands.

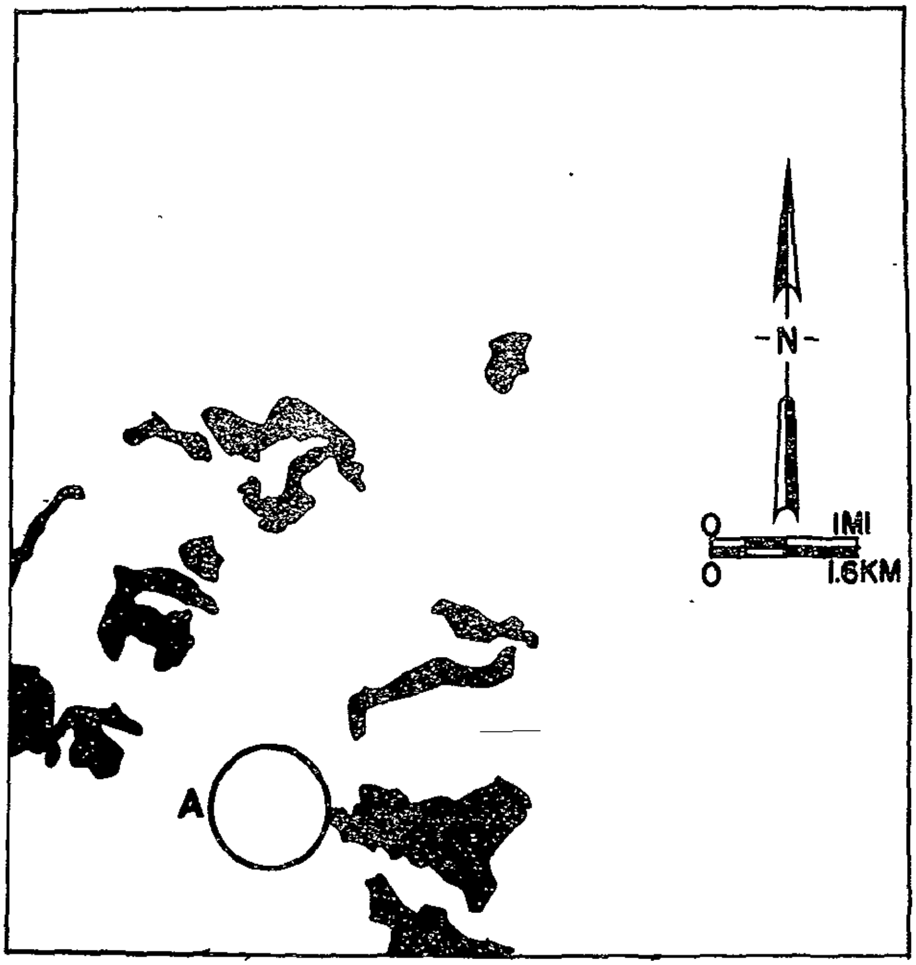

Figure 18. Aspen data interpreted from U.S. Forest Service map of township T4NR5E. Note the absence of stand "A" and the lack of smaller aspen stands throughout the area.

Accuracy measurements have not been completed but initial results indicate a potential for using LANDSAT for initial mapping and subsequent monitoring of aspen in the Black Hills.

FUNDS EXPENDED

Total funds expended through February 29, 1975: $65,084.08 This does not include total costs incurred by state agency participants as they invoice on a quarterly basis.

DATA USE (as of 1 March 76)

Value of Data Allowed - $15,144

Value of Data Ordered - $7,091

Value of Data Received - $7,091

AIRCRAFT DATA

NASA U-2 data collected 23 September was received and, except for vignetting effects on the color infrared imagery, the data are useful. Cloud conditions over certain ground-truthed areas, previously designated as intensive study sites, has necessitated further reliance on high altitude aircraft imagery as a data base. High altitude aircraft imagery has been used as ground truth in land use studies, surface water inventories, and aspen mapping. A USGS Quadrangle map was updated using high altitude aircraft imagery to allow accurate UTM coordinate assignment to a GCP.

PROGRAM FOR NEXT REPORTING PERIOD

Visual interpretations of LANDSAT data will continue in land use mapping and surface water inventory evaluations. Digital analysis of

CCTS using SPB programs and RSI programs (including DIRS) will allow for conclusions and recommendations of the potential value of LANDSAT as a data source. Based on the newly recommended procedures, the basin will be mapped for Level I land use, and surface water inventory. This data will then be entered, along with other pertinent data (e.g. soil association) into a data base. Flood plain mapping, and strip development south of Sturgis along the eastern edge of the Black Hills, will be conducted. Crop identification, using visual and digital temporal procedures is planned. Cost-effective analyses will allow conclusions to be drawn regarding the practicality of LANDSAT as a data source.

CONCLUSIONS

Interpretation of LANDSAT data by participating agency personnel has demonstrated to them the relative ease and speed with which such information as surface water can be obtained from the imagery. Comparisons with 1:24,000 USGS Quadrangle maps specifically, demonstrate the value of such interpretations as they relate to an accurate accounting of Western South Dakota surface water. Land use interpretations while not as straight-forward as surface water, have a benefit over "statistical" methods of land use inventories in that: 1) a spatial map of the land use forms is obtained, 2) the remote sensing data are generally more timely, 3) the remote sensing data are not restricted by political boundaries, and 4) the LANDSAT-based data are easily updated.

RECOMMENDATIONS

Reduced turn-around time for LANDSAT data products would allow for earlier initiation of studies and contribute to the timliness of the results.

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